

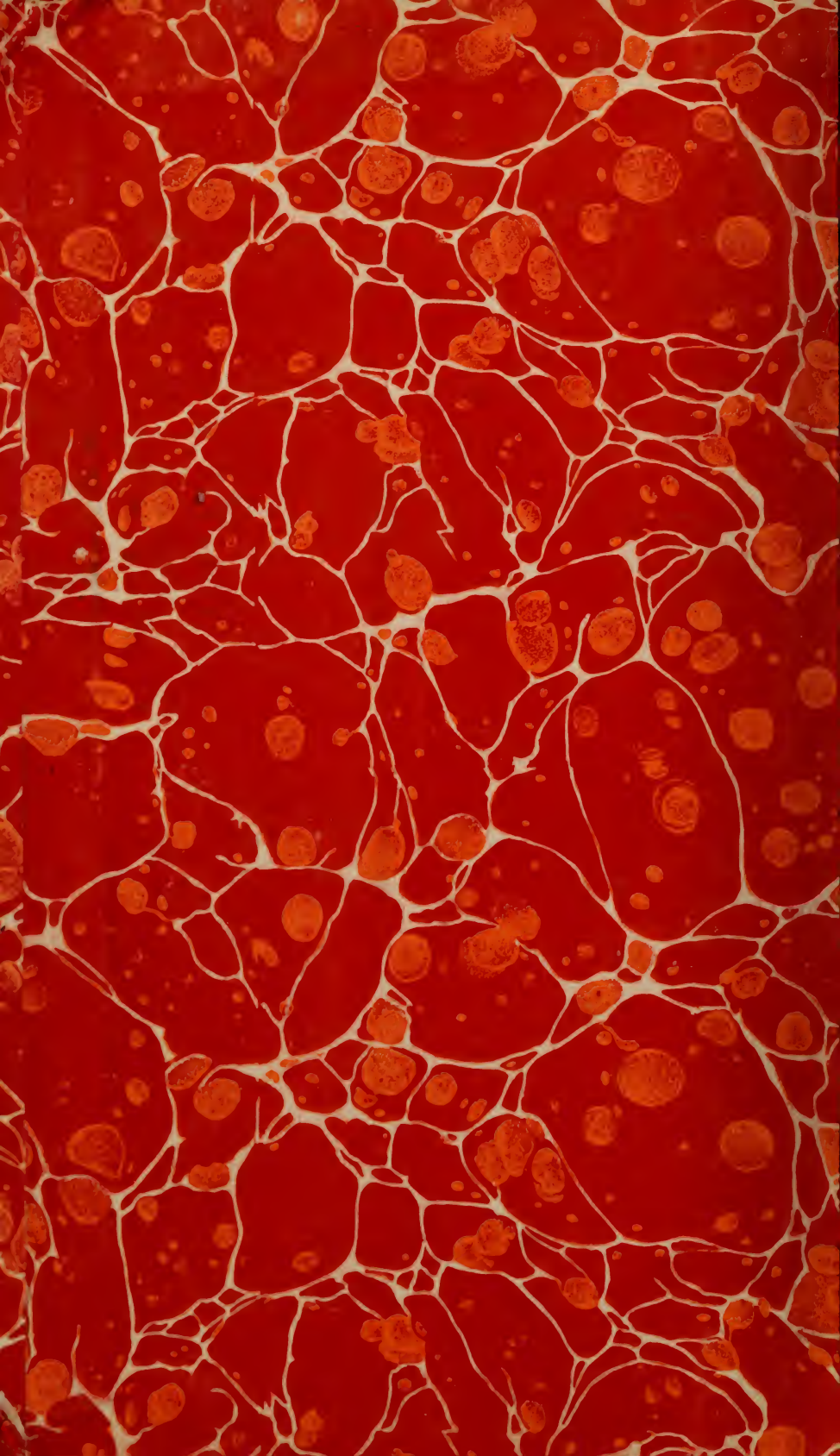
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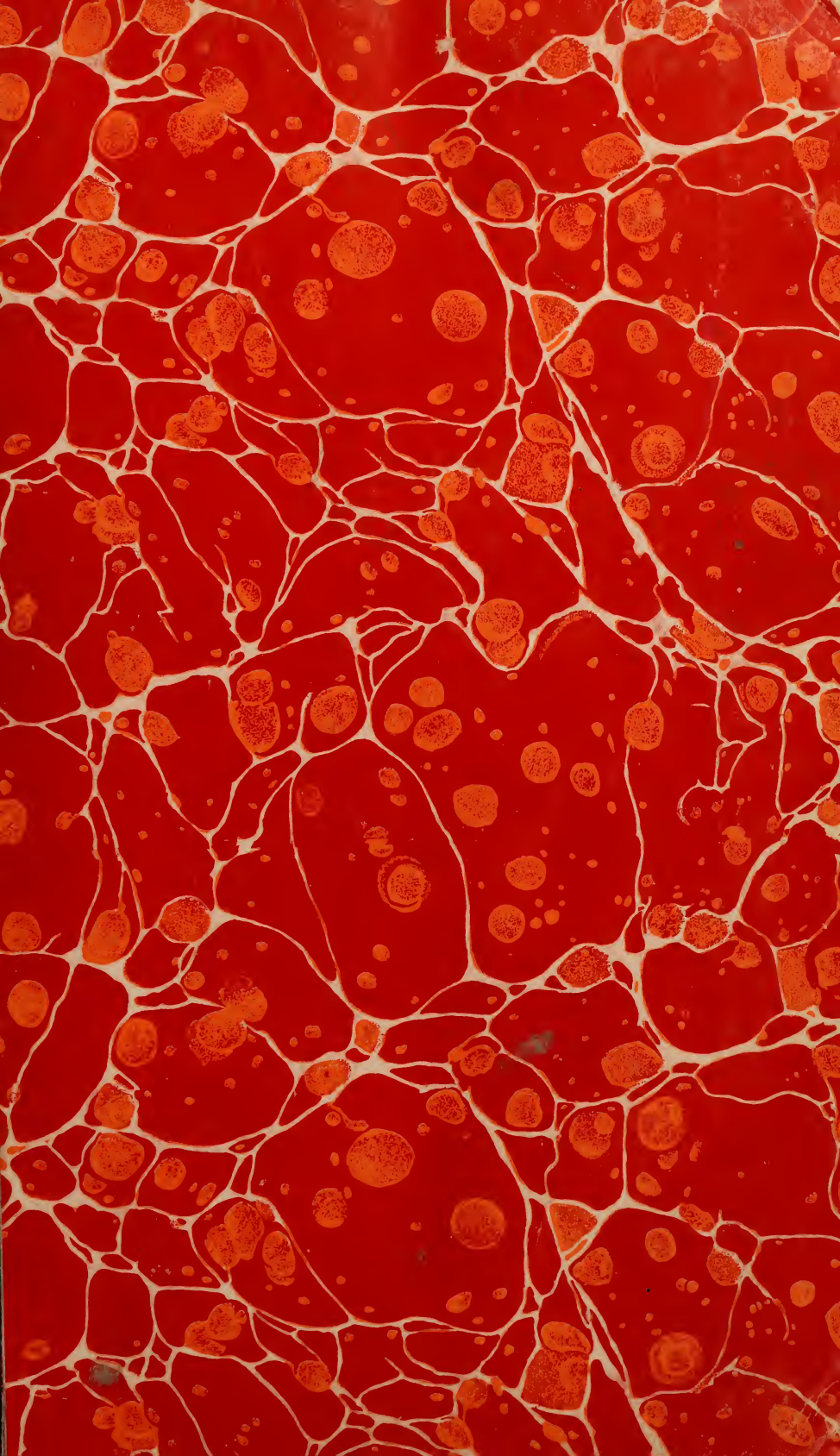
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INFRA-RED SPECTRA OF NEON, ARGON, AND KRYPTON

By William F. Meggers and C. J. Humphreys

ABSTRACT

The first spectra of neon, argon, and krypton have been photographed in the infra-red (7,600 to 12,200 Å) with two new Eastman emulsions having P and Q types of sensitization with sensitivity maxima at 8,600 and 9,700 Å, respectively. The sources were Geissler tubes operated with uncondensed high-voltage a. c. discharges, and the spectrographs were concave gratings of 21 feet radius. About 200 infra-red lines have been photographed in the spectrum of each of the noble gases and analysis has resulted in the confirmation and extension of the tables of spectral terms. Several new hydrogen-like terms from *f*-type electrons have been found in each spectrum, and the 3d terms lacking in the Ar I and Kr I spectra have all been identified. Many of the new lines can be accurately computed from relative terms and such calculated values may serve as preliminary standards of wave lengths in the infra-red.

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I. INTRODUCTION

Neutral atoms of the noble gases are characterized by spectra of exceptional utility and rare beauty. Geissler tubes containing these gases at low pressure when excited by moderate electrical discharges, emit spectral lines of high homogeneity which have been demonstrated to be reproducible within 1 part in 50,000,000. These lines are favorably regarded as standards of wave length, and are extensively used in spectroscopy and metrology. It is not unlikely that one of these lines may ultimately be chosen as the most practical and permanent primary standard of length, especially if an even-numbered isotope can be segregated so that the strongest lines will be free from hyperfine structure.

From a theoretical viewpoint the first spectra of the noble gases are of special interest because they arise in each case from a "closed shell" configuration of electrons, and unlike other complex spectra they are found to consist of extended series of relatively simple types (S, P, D, F terms) and low multiplicities (singlets and triplets). Evidence of a gradual transition from *sl* to *jj* electron coupling as the atomic complexity increases adds interest to a comparison of the spectral structures of all the noble gases.

Both practical and theoretical considerations have been responsible for intensive investigations of the noble gas spectra, and especially for efforts to extend observations to the region of greater wave lengths. Except for a relatively small number of lines in the extreme ultra-violet, each of these spectra exhibits several group series beginning in the red or infra-red and converging to limits in the near ultra-violet or in the visible region. The fact that many of the intrinsically strongest lines of these spectra occur in the infra-red accounts for the

successful photography of a considerable proportion of them even with relatively insensitive materials. Thus the most energetic infra-red lines of Ne, A, Kr, and Xe had already been detected photographically to about $1\ \mu$ with dicyanine or neocyanine sensitized plates when about a year ago the vastly superior infra-red sensitizers, mesocyanine and xenocyanine, were discovered. As soon as the new photographic plates became available for spectrography, the spectroscopy section of this bureau applied them to explorations of infra-red emission spectra, including those characteristic of the noble gases. Preliminary results on this group were reported¹ at a meeting of the American Physical Society last April. In the meantime the observations have been repeated and extended, and details have been published for two of these elements, viz, He² and Xe.³ Data for the intermediate gases, Ne, A, and Kr, are now presented, they consist of wave-length measurements, estimated intensities and series classifications of infra-red lines in the wave length interval 7,600 to 12,200 Å. These results are to be regarded as preliminary or exploratory; they were obtained with spectrographs of moderate dispersion, but the accuracy of measurement is sufficient for purposes of spectral structure analysis, and for the determination of retardations in future interferometric comparisons. Wave lengths corresponding to the stronger lines are being measured with increased precision by the Fabry-Perot interferometer method and will be presented in a subsequent paper on standard wave lengths in the infra-red. In the meantime values computed from accurately fixed relative terms may serve as proper standards in this range, since the accuracy of such calculated values may be expected to exceed that of the preliminary observations.

The spark spectra of the heavier noble gases are also rich in infra-red lines, but their description is reserved for later publication.

II. WAVE-LENGTH MEASUREMENTS

Geissler tubes of glass purchased from Robert Goetze in Leipzig served as sources of radiation. Each tube has two cylindrical electrode bulbs connected by a capillary of 11 cm length and about 1 mm bore, the viewing end of which is inclosed in a thin-walled glass bulb of 2.5 cm diameter. Such tubes can be viewed either side on or end on, the latter being preferred on account of increased intensity.⁴ In the experiments here reported the tube was always mounted with its capillary on the axis of the spectrograph with the viewing end directed toward the slit, the capillary bore being imaged on the slit with a condensing lens.

The tubes were filled with exceptionally pure gases at sufficient pressure to insure relatively long life in spite of gradual gas disappearance accompanying electrode sputtering. To produce the first spectrum the tube was operated with uncondensed electrical discharges from a. c. transformers, the current through the tube being about 20 ma. Under these conditions no spark lines appeared in the spectral interval under investigation. Spectrochemical analysis revealed a trace of O in the Ne, no impurities in the A, a small amount of A and Xe in the Kr and a trace of Kr in the Xe.

¹ W. F. Meggers and C. J. Humphreys, *Phys. Rev.*, vol. 40, p. 1040, 1932.

² W. F. Meggers and G. H. Dieke, *B. S. Jour. Research*, vol. 9 (RP462), p. 121, 1932.

³ C. J. Humphreys and W. F. Meggers, *B. S. Jour. Research*, vol. 10, (RP521) p. 139, 1933.

⁴ End-on use of these sources is objectionable in interferometry on account of self-reversal phenomena then appearing on lines involving normal or metastable states.

The spectrograms were made with two concave diffraction gratings of 21 feet radius of curvature, each mounted in parallel light from a mirror of similar radius.⁵ One grating has 20,000 lines per inch and the other 7,500 lines per inch, their scales in the first-order red spectrum are 3.7 and 10.2 Å/mm, respectively. The larger dispersion was applied to the interval 7,600 to 9,200 Å, while the smaller scale was used over the entire range 7,600 to 12,200 Å. On each spectrogram the spectrum of the iron arc was recorded in the second and third orders of the grating alongside the spectrum of the noble gas which was photographed in the first order with a red glass filter in front of the slit to remove overlapping higher orders. Wave-length measurements were then made relative to international standards in the iron spectrum, doubling or trebling their values to obtain effective standards in the infra-red range. The final scale of these measurements was adjusted slightly to bring it into accord with preliminary values derived from interferometer comparisons of the stronger lines. Wave-length measurements from the larger scale spectrograms should not contain errors exceeding one or two hundredths of an angstrom unit, but the remainder may have an average error two or three times as large.

Exposure times were usually 16 to 24 hours, but one 48-hour exposure was made for each gas in order to record as many lines as possible beyond 11,000 Å where the photographic sensitivity is very low. Under these conditions the stronger lines were tremendously overexposed, and were accompanied by numerous Rowland ghosts from which the wave length of the parent line could be derived with higher accuracy than from measurements of the greatly widened primary image. All such ghosts were removed from the final lists. Lyman ghosts⁶ were sought but only one was found, a line observed for Kr at 12,282 Å being interpreted as $(7/5-1/1,500)$ 8,776.75 Å.

Photographic plates with P and Q types of sensitizing as prepared by the research laboratory of the Eastman Kodak Co.⁷ were employed. These plates are sensitized to infra-red radiation with new dyes which have been named mesocyanine and xenocyanine. The former has a relatively narrow sensitizing band with a strong maximum at 8,600 Å, while the latter has a much broader band with a maximum action at wave length 9,700 Å. The P-type plates were used in the interval 7,600 to 9,200 Å, and the Q-type in the range 8,500 to 12,200 Å. Both types of plates were hypersensitized by bathing from 1 to 5 minutes in a dilute ammonia solution, rinsing in alcohol, and drying in a current of air. After exposure they were developed for 5 minutes in Eastman's X-ray developer at a temperature of about 18° C.

III. RESULTS

1. NEON

Paschen's⁸ description and analysis of the spectrum of neon has served as a model for the remaining noble gases. A special notation which was proposed by Paschen to represent the spectral terms of neon has been retained in describing the first spectrum of the remaining gases of this group. A translation into the notation now in general use, while highly desirable, is not feasible at present, because of the

⁵ W. F. Meggers and Kevin Burns, B. S. Sci. Papers, vol. 18 (S441), p. 191, 1922.

⁶ W. F. Meggers and C. C. Kiess, J. Opt. Soc. Am. and Rev. Sci. Inst., vol. 6, p. 417, 1922.

⁷ C. E. K. Mees, J. Opt. Soc. Am., vol. 22, p. 204, 1932. Addendum, April, 1932.

⁸ F. Paschen, Ann. der Physik, vol. 60, p. 405, 1919.

overlapping of the multiplets, the fact that the Landé interval rule and theoretical Zeeman effects are usually violated in these spectra, and on account of ambiguities in the correlation of levels with their series limits. Nothing was added to the results for neon until Gremmer⁹ found some new lines by exposing neocyanine plates 36 to 60 hours. These additional lines fixed, by means of new combinations, four 2s terms for which only series interpolated values could be given by Paschen. Altogether Gremmer added 27 classified lines to the infra-red between 7,944.22 and 9,665.40 Å. By employing an efficient spectograph, an intense source, and very long exposures, Rasmussen¹⁰ recorded on neocyanine plates 7 new lines in the neon spectrum (10,296 to 11,178 Å), which were classified as 2p-2s combinations.

The infra-red spectrum of neon was investigated with a spectrometer, thermopile, and galvanometer by Hardy¹¹, who observed 30 lines ranging in wave length from 9,667.6 to 18,552 Å. We have recorded 16 of these lines photographically, the last one being 12,066.4 Å, and have adopted Hardy's values for the remainder, with a correction of -2.6 Å applied to them, since the lines observed by both methods differ by this amount on the average. Comparison of galvanometer deflections with estimated photographic intensities gives a rough calibration of the spectral sensitivity of a xenocyanine plate, at 11,000 Å the sensitivity is less than one-tenth that of the maximum near 9,700 Å and at 12,000 Å it has declined to less than one one-thousandth.

Complete results now available for the infra-red spectrum of neon are presented in Table 1, where the intensity, observed wave length, vacuum wave number, symbolic-term difference, and numerical-term difference appear in successive columns. Wave lengths given to 3 decimals are quoted from Paschen's publication; they represent interferometer measurements of high precision. The vacuum wave numbers were taken from Kayser's¹² table for wave lengths up to 10,000 Å, beyond which they were obtained by computing the reciprocal of the wave lengths corrected to vacuum values with the aid of the atmospheric dispersion formula of Meggers and Peters.¹³

TABLE 1.—*Infra-red spectrum of neon*

Intensity	λ_{air} I. Å.	ν_{vac} cm ⁻¹ observed	Term combination	ν_{vac} cm ⁻¹ calculated
Hardy	Hardy			
1	18,549	5,389.7	$3d_1'-4W$	5,390
1	18,430	5,424.5	$3s_1'''-4V$	5,425.2
2	18,386.4	5,437.32	$\{3s_1'''-4T$	5,437.2
1	18,306.4	5,461.08	$\{3s_1'''-4U$	5,438.1
			$3d_3-4Y$	5,462.02
3	18,271.4	5,471.54	$3d_3-4Z$	5,471
1	18,078.4	5,529.96	$3d_5-4X$	5,528.50
1	17,165.4	5,824.08	$2p_1-2s_4$	5,825.25
2	15,234.4	6,562.28	$2p_1-2s_2$	6,563.85
1	13,219.4	7,562.58	$2p_2-2s_3$	7,562.69

⁹ W. Gremmer, *Zeitschr. f. Phys.*, vol. 50, p. 716, 1928.

¹⁰ E. Rasmussen, Dissertation, Copenhagen, 1932.

¹¹ J. D. Hardy, *Phys. Rev.*, vol. 38, p. 2162, 1931.

¹² H. Kayser, *Tabelle der Schwingungszahlen*, Leipzig, 1925.

¹³ W. F. Meggers and C. G. Peters, *B. S. Sci. Papers*, vol. 14 (S327), p. 722, 1918.

TABLE 1.—*Infra-red spectrum of neon*—Continued

Intensity	λ_{air} I. A.	ν_{vac} cm ⁻¹ observed	Term combination	ν_{vac} cm ⁻¹ calculated
Hardy	Hardy			
2	12,912.4	7,742.40	$2p_4-2s_5$	7,742.63
0.3	12,767.4	7,830.30	$2p_5-2s_5$	7,829.03
2	12,690.1	7,877.99	$2p_3-2s_4$	7,878.54
1	12,594.8	7,937.64	$2p_4-2s_4$	7,937.47
1	12,453.4	8,024.52	$2p_5-2s_4$	8,023.87
B. S.	B. S.			
1	12,066.4	8,285.21	$2p_6-2s_5$	8,285.28
1	11,985.1	8,341.40	$2p_2-2s_3$	8,341.53
3	11,789.0	8,480.17	$2p_6-2s_4$	8,480.12
4	11,766.9	8,496.10	$2p_2-2s_2$	8,496.13
1	11,688.1	8,553.37	$2p_1-3d_5$	8,553.485
3	11,614.20	8,607.80	$2p_5-2s_3$	8,607.87
2	11,536.35	8,665.89	$2p_1-3d_2$	8,665.865
4	11,525.10	8,674.34	$2p_7-2s_4$	8,674.38
8	11,522.83	8,676.05	$2p_4-2s_2$	8,676.07
4	11,409.27	8,762.41	$2p_5-2s_2$	8,762.47
5	11,390.50	8,776.85	$2p_8-2s_5$	8,776.92
15	11,177.51	8,944.09	$2p_9-2s_5$	8,944.10
30	11,143.04	8,971.76	$2p_8-2s_4$	8,971.76
1	11,120.3	8,990.11	$2s_2-4p_3$	8,990.16
3	11,049.6	9,047.63	$2s_5-4p_6$	9,047.60
2	11,044.1	9,052.13	$2s_2-4p_1$	9,052.43
2	11,020.8	9,071.27	$2s_4-4p_3$	9,071.32
3	10,888.4	9,181.57	$3d_1'-6Z$	9,181.6
2	10,886.1	9,183.51	$3d_1''-6Z$	9,183.4
200	10,844.47	9,218.77	$2p_6-2s_2$	9,218.72
4	10,830.33	9,230.80		
2	10,819.9	9,239.70	$3s_1''-6U$	9,239.92
1	10,814.7	9,244.1	$3d_2-6Y$	9,244.2
2	10,808.1	9,249.8	$3s_1'''-6U$	9,249.68
2	10,806.3	9,251.3	$3s_1''''-6U$	9,251.24
100	10,798.02	9,258.42	$2p_7-2s_3$	9,258.38
2	10,780.40	9,273.56	$3d_3-7Y$	9,273.6
3	10,766.03	9,285.93	$3d_1'-6W$	9,285.93
4	10,763.98	9,287.70	$3d_1''-6W$	9,287.70
1?	10,760.4	9,290.8	$3d_4-6Z$	9,290.9
1?	10,758.2	9,292.7	$3d_4'-6Z$	9,292.7
3	10,690.35	9,351.67	$3d_5-6X$	9,351.64
1	10,673.7	9,366.3	$3d_6-6X$	9,366.28
30	10,620.63	9,413.01	$2p_7-2s_2$	9,412.98
300	10,562.38	9,564.97	$2p_1-3s_1'$	9,464.941
3	10,432.53	9,582.77	$2s_4-4p_4$	9,582.82
80	10,295.40	9,710.41	$2p_8-2s_2$	9,710.36
1	10,267.0	9,737.28		
7	10,245.70	9,757.51	$2s_5-4p_2$	9,757.56
2	10,224.6	9,777.65	$2s_5-4p_4$	9,777.66
2	10,210.73	9,790.93	$2s_4-4p_1$	9,791.03
3	10,091.53	9,906.59	$3s_1'''-8W$	9,906.5
1	10,057.6	9,940.0		
2	10,038.9	9,958.5	$3d_1'-6U$	9,958.47
2	10,037.1	9,960.3	$3d_1''-6U$	9,960.24

TABLE 1.—*Infra-red spectrum of neon*—Continued

Intensity	$\lambda_{\text{air I. A.}}$	$\nu_{\text{vac cm}^{-1}}$ observed	Term combination	$\nu_{\text{vac cm}^{-1}}$ calculated
B. S.	B. S.			
4	10,008.55	9,988.72	$3d_1'-7Y$	9,988.68
30	10,007.31	9,989.96	$3d_1'-7Z$	9,989.94
20	10,005.54	9,991.72	$3d_1''-7Z$	9,991.71
1	10,000.9	9,996.4		
2	9,974.2	10,023.1	$3d_2-6U$	10,023.27
6	9,963.55	10,033.84	$3s_1'-7U$	10,033.82
15	9,947.94	10,049.58	$3s_1''-7U$	10,049.54
2	9,944.9	10,052.6	$3d_3-6U$	10,052.68
7h	9,944.1	10,053.5	$3d_2-7Y$	10,053.48
15	9,938.35	10,059.28	$3s_1'''-7U$	10,059.30
10	9,936.83	10,060.81	$3s_1''''-7U$	10,060.86
4	9,918.52	10,079.39	$3d_3-7X$	10,079.40
20	9,915.13	10,082.83	$3d_3-7Y$	10,082.89
30	9,902.31	10,095.89	$3d_1'-7W$	10,095.88
40	9,900.58	10,097.64	$3d_1''-7W$	10,097.65
2	9,899.06	10,099.20	$3d_4-7Z$	10,099.21
3	9,897.30	10,101.00	$3d_4-7Z$	10,101.04
2	9,875.90	10,122.88	$3d_1''-6p_5$	10,122.7
20	9,837.47	10,162.43	$3d_5-7X$	10,162.37
5	9,823.42	10,176.97	$3d_2-6p_1$	10,176.90
1	9,807.0	10,194.0		
2	9,788.1	10,213.7	$2s_2-5p_{10}$	10,213.58
2	9,760.57	10,242.50		
1	9,744.2	10,259.7		
1	9,741.3	10,262.9	$3d_6-7p_{10}?$	10,263.4
1	9,728.2	10,276.6	$3s_1''-9W$	10,276.74
1	9,724.8	10,280.2	$2s_2-5p_8$	10,280.16
3	9,702.40	10,303.90	$3d_5-6p_4$	10,303.8
1,000	9,665.426	10,343.33	$2p_{10}-2s_5$	10,343.34
3	9,658.5	10,350.7		
1	9,642.2	10,368.2	$2s_3-5p_{10}$	10,368.18
2	9,620.8	10,391.3		
5	9,592.19	10,422.29		
3	9,584.79	10,430.34		
2	9,573.99	10,442.10	$2s_2-5p_3$	10,442.22
300	9,547.40	10,471.18	$2p_2-3d_6$	10,471.128
500	9,534.17	10,485.71	$2p_2-3d_5$	10,485.770
5?+g	9,508.4	10,514.1	$3d_1''-8Z$	10,513.82
3	9,506.59	10,516.14		
2	9,497.9	10,525.8		
500	9,486.68	10,538.21	$2p_{10}-2s_4$	10,538.18
2h	9,467.8	10,559.2	$3s_1'-8U$	10,559.1
300	9,459.21	10,568.81	$2p_2-3d_3$	10,568.744
1	9,454.0	10,574.6	$3s_1''-8U$	10,574.8
10	9,452.08	10,576.78	$3d_2-8Z?$	10,576.85
3	9,445.26	10,584.42	$\{3d_2-8Y$ $3s_1'''-8U$	10,584.41 10,584.5
2	9,443.8	10,586.1	$3s_1''''-8U$	10,586.1
40	9,432.94	10,598.24	$2p_2-3d_2$	10,598.150
500	9,425.38	10,606.74	$2p_3-3d_5$	10,606.782

TABLE 1.—*Infra-red spectrum of neon*—Continued

Intensity	λ_{air} I. A.	ν_{vac} cm ⁻¹ observed	Term combination	ν_{vac} cm ⁻¹ calculated
B. S.	B. S.			
4	9, 412. 32	10, 621. 46	$3d_4$ -8Z	10, 621. 32
6	9, 410. 75	10, 623. 23	$3d_4'$ -8Z	10, 623. 15
8	9, 405. 75	10, 628. 88	$3d_4$ -8Y	10, 628. 88
2	9, 393. 8	10, 642. 4		
5	9, 377. 2	10, 661. 2	$2p_2$ - $3d_1''$	10, 661. 187
200	9, 373. 28	10, 665. 70	$2p_4$ - $3d_5$	10, 665. 711
3	9, 353. 3	10, 688. 5	$3d_5$ -8X	10, 688. 48
2	9, 340. 5	10, 703. 1	$3d_6$ -8X	10, 703. 12
1?	9, 335. 0	10, 709. 4	$3d_3$ -8W	10, 709. 5
600	9, 326. 52	10, 719. 17	$2p_3$ - $3d_2$	10, 719. 162
300	9, 313. 98	10, 733. 61	$2p_4$ - $3d_4$	10, 733. 621
150	9, 310. 58	10, 737. 52	$2p_5$ - $3d_6$	10, 737. 467
600	9, 300. 85	10, 748. 76	$2p_4$ - $3d_3$	10, 748. 685
100	9, 275. 53	10, 778. 10	$2p_4$ - $3d_2$	10, 778. 091
1	9, 237. 4	10, 822. 6		
200	9, 226. 67	10, 835. 17	$2p_5$ - $3d_3$	10, 835. 083
200	9, 221. 59	10, 841. 14	$2p_4$ - $3d_1''$	10, 841. 128
400	9, 220. 05	10, 842. 95	$2p_4$ - $3d_1'$	10, 842. 893
1?	9, 214. 5	10, 849. 5	$3d_1'-1, 378. 6$	10, 849. 5
2	9, 212. 9	10, 851. 4	$3d_1''-1, 378. 6$	10, 851. 3
600	9, 201. 76	10, 864. 51	$2p_5$ - $3d_2$	10, 864. 489
1?	9, 193. 8	10, 873. 9	$3d_1''-7p_5$	10, 874. 0
3	9, 191. 8	10, 876. 3		
600	9, 148. 68	10, 927. 54	$2p_5$ - $3d_1''$	10, 927. 526
1	9, 123. 2	10, 958. 1	$3d_4-1, 378. 6$	10, 958. 7
20	9, 121. 14	10, 960. 54	$3d_4'-1, 378. 6$	10, 960. 5
1?	9, 115. 3	10, 967. 6	$3d_3$ -9Y	10, 967. 6
1	9, 111. 8	10, 971. 8		
3	9, 103. 53	10, 981. 74	$3d_4$ -9Z	10, 981. 74
1	9, 102. 1	10, 983. 5	$3d_4'$ -9Z	10, 983. 57
3	9, 094. 9	10, 992. 1		
1	9, 088. 5	10, 999. 9		
1	9, 078. 2	11, 012. 4		
8	9, 073. 04	11, 018. 64	$2s_4$ - $5p_8$	11, 018. 66
2	9, 069. 7	11, 022. 7		
1	9, 062. 6	11, 031. 3		
1	9, 061. 5	11, 032. 7		
6	9, 052. 54	11, 043. 60	$2s_4$ - $5p_7$	11, 043. 52
3	9, 049. 06	11, 047. 84	$2s_4$ - $5p_6$	11, 047. 88
1	9, 046. 8	11, 050. 6	$3d_5$ -9Y	11, 050. 6
2	9, 045. 4	11, 052. 3		
3	9, 039. 0	11, 060. 1	$3d_2$ -9W	11, 060. 09
6	9, 036. 98	11, 062. 61	$2s_2$ - $5p_4$	11, 062. 72
200	8, 988. 58	11, 122. 18	$2p_{10}$ - $2s_3$	11, 122. 18
2	8, 968. 6	11, 146. 9	$2s_5$ - $5p_{10}$	11, 147. 02
3	8, 962. 34	11, 154. 74	$2s_2$ - $5p_1$	11, 154. 83
7	8, 948. 12	11, 172. 47	$3d_5$ -9W	11, 172. 47
6	8, 941. 47	11, 180. 78	$2s_4$ - $5p_3$	11, 180. 82
10	8, 929. 24	11, 196. 09	$2s_5$ - $5p_9$	11, 196. 03
2	8, 927. 4	11, 198. 4	$2s_3$ - $5p_2$	11, 198. 49

TABLE 1.—*Infra-red spectrum of neon—Continued*

Intensity	λ_{air} I. A.	ν_{vac} cm ⁻¹ observed	Term combi- nation	ν_{vac} cm ⁻¹ calculated
B. S.	B. S.			
300	8, 919. 50	11, 208. 31	$2p_6-3d_5$	11, 208. 353
3	8, 915. 44	11, 213. 42	$2s_5-5p_8$	11, 213. 60
3	8, 913. 0	11, 216. 5		
2	8, 895. 6	11, 238. 4	$2s_5-5p_7$	11, 238. 36
10	8, 892. 22	11, 242. 70	$2s_5-5p_6$	11, 242. 72
500	8, 865. 76	11, 276. 25	$2p_{10}-2s_2$	11, 276. 263
100	8, 865. 33	11, 276. 80	$2p_6-3d_4$	11, 276. 78
700	8, 853. 88	11, 291. 39	$2p_6-3d_3$	11, 291. 327
2	8, 842. 1	11, 306. 4		
50	8, 830. 92	11, 320. 74	$2p_6-3d_2$	11, 320. 733
6	8, 820. 36	11, 334. 30		
30	8, 792. 51	11, 370. 20	$2p_2-3s_1''''$	11, 370. 185
1, 000	8, 783. 78	11, 381. 50	$2p_2-3s_1'''$	11, 381. 505
50	8, 732. 01	11, 383. 79	$2p_6-3d_1''$	11, 383. 770
1, 200	8, 780. 65	11, 385. 56	$2p_6-3d_1'$	11, 385. 535
150	8, 773. 75	11, 388. 02	$2p_7-3d_6$	11, 387. 977
400	8, 771. 70	11, 397. 17	$2p_2-3s_1'$	11, 397. 226
15	8, 767. 55	11, 402. 57	$2p_7-3d_5$	11, 402. 619
200	8, 704. 15	11, 485. 62	$2p_7-3d_3$	11, 485. 593
500	8, 681. 94	11, 515. 00	$2p_7-3d_2$	11, 514. 999
500	8, 679. 51	11, 518. 23	$2p_3-3s_1'$	11, 518. 238
400	8, 654. 51	11, 550. 17	$2p_4-3s_1''''$	11, 550. 126
1, 500	8, 654. 380	11, 551. 673	$2p_4-3s_1'''$	11, 551. 687
300	8, 647. 05	11, 561. 46	$2p_4-3s_1''$	11, 561. 446
50	8, 635. 31	11, 577. 18	$2p_4-3s_1'$	11, 577. 167
600	8, 634. 668	11, 578. 044	$2p_7-3d_1''$	11, 578. 036
400	8, 591. 266	11, 636. 535	$2p_5-3s_1''''$	11, 636. 524
60	8, 582. 91	11, 647. 86	$2p_5-3s_1'''$	11, 647. 844
100	8, 571. 36	11, 663. 56	$2p_5-3s_1'$	11, 663. 565
60	8, 544. 70	11, 699. 95	$2p_8-3d_5$	11, 699. 996
500	8, 495. 359	11, 767. 904	$2p_8-3d_4$	11, 767. 906
80	8, 484. 45	11, 783. 03	$2p_8-3d_3$	11, 782. 970
150	8, 463. 37	11, 812. 38	$2p_8-3d_2$	11, 812. 376
400	8, 418. 447	11, 875. 416	$2p_8-3d_1''$	11, 875. 413
100	8, 417. 18	11, 877. 20	$2p_8-3d_1'$	11, 877. 178
800	8, 377. 630	11, 933. 274	$2p_9-3d_4'$	11, 933. 260
200	8, 376. 41	11, 935. 02	$2p_9-3d_4$	11, 935. 088
150	8, 365. 75	11, 950. 22	$2p_9-3d_3$	11, 950. 152
150	8, 301. 54	12, 042. 65	$2p_9-3d_1''$	12, 042. 595
600	8, 300. 338	12, 044. 396	$2p_9-3d_1'$	12, 044. 360
80	8, 267. 11	12, 092. 81	$2p_6-3s_1''''$	12, 092. 768
250	8, 266. 092	12, 094. 293	$2p_6-3s_1'''$	12, 094. 329
150	8, 259. 392	12, 104. 105	$2p_6-3s_1''$	12, 104. 088
30	8, 248. 70	12, 119. 80	$2p_6-3s_1'$	12, 119. 809
300	8, 136. 423	12, 287. 039	$2p_7-3s_1''''$	12, 287. 034
60	8, 128. 93	12, 298. 36	$2p_7-3s_1''$	12, 298. 354
100	8, 118. 554	12, 314. 088	$2p_7-3s_1'$	12, 314. 075
2	8, 093. 08	12, 352. 84	$2s_3-6p_3$	12, 352. 85
200	8, 082. 460	12, 369. 074	$1s_2-2p_{10}$	12, 369. 077
1	8, 076. 06	12, 378. 88	$2s_2-6p_1$	12, 378. 92

TABLE 1.—*Infra-red spectrum of neon*—Continued

Intensity	λ_{air} I. A.	ν_{vac} cm ⁻¹ observed	Term combination	ν_{vac} cm ⁻¹ calculated
B. S.	B. S.			
2	8,041.79	12,431.63	$2s_5-6p_0$	12,431.77
2	8,024.11	12,459.02	$2s_5-6p_6$	12,459.16
20	7,944.16	12,584.41	$2p_8-3s_1''''$	12,584.411
200	7,943.193	12,585.938	$2p_8-3s_1'''$	12,585.972
70	7,937.00	12,595.76	$2p_8-3s_1''$	12,595.731
40	7,927.13	12,611.44	$2p_8-3s_1'$	12,611.452
1	7,840.04	12,751.53	$2p_9-3s_1''''$	12,751.593
30	7,839.08	12,753.10	$2p_9-3s_1'''$	12,753.154
7	7,833.06	12,762.90	$2p_9-3s_1''$	12,762.913
10	7,724.63	12,942.05	$2p_1-3s_4$	12,942.039
(Paschen)	(Paschen)			
0.5	2,994.410	33,385.84	$1s_4-4V$	33,385.9
1	2,994.250	33,387.63	$1s_4-4U$	33,387.5
2	2,957.293	33,804.85	$1s_5-4U$	33,804.9
0.5	2,957.148	33,806.50	$1s_5-4T$	33,806.5
3	2,755.82	36,276.2	$1s_5-5U$	36,276.2

Wave lengths exceeding 12,066.4 Å are quoted from Hardy's paper, with a correction of -2.6 Å. Analysis of these data showed that a large majority of the 200 infra-red lines observed for neon could be accounted for as combinations of established terms, thus confirming the identity of these terms. About 60 faint lines between 9,100 and 10,900 Å appear to represent combinations of $3d$ terms with higher members of f -type series, and most of these lines have been so classified. Only two terms of this type, $4x$ and $4y$ were known heretofore. Hardy states that "the lines in the region around 1.8μ are apparently due to combinations between the $3d$ levels and the x and y groups, and although the wave lengths have been checked as well as possible the agreement with the calculated frequencies from the known terms does not check very well with the experimental values." Our interpretation of these lines accounts for only two of them as combinations $3d-4x, y$ while the remainder appear to be combinations $3d-4z, u, v, w, t$, thus adding five new f -type terms. Three of the latter, $4u, v, t$ are first members of non-Ritzian series and are checked by combinations with $1s$ terms which represent previously unclassified lines in the ultra-violet, now presented at the end of Table 1. The infra-red data are insufficient to establish any of the 5 f terms with certainty, but their approximate values can be obtained from interpolation.

In order to facilitate the comparison of results in Table 1 with the identified spectral terms of neon the latter are collected in Table 2. These data have not been presented in this condensed form heretofore.

2. ARGON

An extensive description and analysis of the first spectrum of argon was published by Meissner¹⁴ who found the structure of this spectrum very similar to that of neon. Several groups of terms ($2s$, $3d$, etc.) could not be established because their strongest combinations lay out of range of Meissner's observations in the infra-red. Gremmer¹⁵ observed 36 new lines in the infra-red, but only 8 of these were explained by Meissner's terms, and 9 of them are not present on our spectrograms.

Important additions to the data for argon were made by Rasmussen¹⁶ who succeeded, with an efficient spectrograph, an intense light source, and very long exposures to neocyanine plates, in recording infra-red lines to 10,683.4 Å. The $2s$ terms, 5 of the $3d$ terms, and several additional f terms were identified from these observations.

TABLE 3.—Infra-red spectrum of argon

Intensity	λ_{air} I. A.	ν_{vac} cm ⁻¹ observed	Term combination	ν_{vac} cm ⁻¹ calculated
Paschen	Paschen			
4	13,719.9	7,287.3	$2p_9-3d_4'$	7,287.60
4	13,504.6	7,402.9	$2p_8-3d_4$	7,403.12
31	12,499	7,998.5	$2p_9-2s_5$	8,005.65
B. S.	B. S.			
1	11,720.0	8,530.1	$2p_8-3d_2$	8,530.29
2	11,668.9	8,567.44	$2p_6-3s_1''$	8,567.56
5	11,488.1	8,702.31	$1s_2-2p_{10}$	8,702.20
2	11,441.7	8,737.59	$2p_6-2s_2$	8,737.50
1	11,393.53	8,774.52	$2p_7-2s_3$	8,774.30
2	11,106.41	9,001.35	$3d_1'-5U$	9,001.19
5	11,078.87	9,023.72	$2p_8-3s_1'''$	9,023.67
5	10,950.73	9,129.31	$2p_6-3s_1'$	9,129.31
2	10,892.39	9,178.21	$2p_9-3s_1'''$	9,178.24
10	10,880.92	9,187.88	$2p_8-3s_1''$	9,187.78
1	10,860.95	9,204.78	$2p_8-3s_1'''$	9,204.69
4	10,773.33	9,279.64	$2p_7-3s_1'$	9,279.60
2	10,770.33	9,282.22	$3d_4''-5Y$	9,282.17
6	10,759.12	9,291.90	$3d_4''-5U$	9,291.97
5	10,733.88	9,313.74	$3s_1'''-5W$	9,313.81
1	10,722.1	9,323.98	$2p_{10}-3d_1''$	9,324.00
4	10,712.76	9,332.11	$3s_1''-5Z$	9,332.13
8	10,700.97	9,342.39	$2p_9-3s_1''$	9,342.35
3	10,683.40	9,357.76	$2p_8-2s_2$	9,357.72
40	10,681.80	9,359.16	$2p_9-3s_1'''$	9,359.36
100	10,673.61	9,366.35	$2p_{10}-2s_5$	9,366.37
10	10,529.31	9,494.70	$3s_1'''-5W$	9,494.83
30	10,506.48	9,515.33	$3d_3-4Z$	9,515.46
100	10,478.09	9,541.11	$2p_{10}-2s_4$	9,541.11
300	10,470.09	9,548.41	$1s_3-2p_{10}$	9,548.36
1	10,357.6	9,652.1	$3d_5-4p_5$	9,652.27
60	10,332.76	9,675.31	$3d_4-5V$	9,675.34

¹⁴ K. W. Meissner, *Zeitschr. f. Phys.*, vol. 37, p. 238, 1926; vol. 39, p. 172, 1926; vol. 40, p. 839, 1927.¹⁵ W. Gremmer, *Zeitschr. f. Phys.*, vol. 50, p. 721, 1928.¹⁶ E. Rasmussen, *Zeitschr. f. Phys.*, vol. 75, p. 695, 1932.

TABLE 3.—*Infra-red spectrum of argon—Continued*

Intensity	$\lambda_{\text{air I. A.}}$	$\nu_{\text{vac cm}^{-1}}$ observed	Term combi- nation	$\nu_{\text{vac cm}^{-1}}$ calculated
B. S.	B. S.			
2	10, 319. 62	9, 687. 62	$3d_4-5Y$	9, 687. 76
20	10, 309. 15	9, 697. 47	$3d_4-5U$	9, 697. 58
1	10, 266. 79	9, 737. 48	$2s_5-5p_9$	9, 737. 40
10	10, 254. 04	9, 749. 58	$2p_8-3s_1'$	9, 749. 53
1	10, 208. 7	9, 792. 88	$2s_5-5p_6$	9, 793. 32
1	10, 206. 9	9, 794. 6	$3d_1''-5p_8$	9, 794. 77
1	10, 171. 2	9, 828. 98	$3d_1''-5p_7$	9, 828. 99
30	10, 163. 45	9, 836. 49	$3d_5-4Z$	9, 836. 44
4	10, 104. 82	9, 893. 56	$3d_2-6X$	9, 893. 53
8	10, 094. 32	9, 903. 85	$3d_2-6Y$	9, 903. 99
50	10, 069. 04	9, 928. 71	$2p_1-4d_5$	9, 928. 76
150	10, 052. 10	9, 945. 45	$3d_4'-5V$	9, 945. 43
2	10, 039. 75	9, 957. 68	$3d_4'-5Y?$	9, 957. 85
40	10, 029. 70	9, 967. 65	$3d_4'-5U$	9, 967. 65
3	10, 007. 61	9, 989. 66	$3d_2-5Z$	9, 989. 62
1	9, 994. 94	10, 002. 32	$3s_1''''-5p_4$	10, 002. 54
20	9, 951. 88	10, 045. 60	$2p_{10}-3d_2$	10, 045. 58
1	9, 937. 80	10, 059. 83	$3s_1''-7Y$	10, 060. 20
6	9, 882. 18	10, 161. 45	$3s_1'-6Z$	10, 116. 34
1	9, 815. 22	10, 185. 47	$3d_4-5p_9$	10, 185. 36
4	9, 800. 92	10, 200. 33	$3d_4-5p_8$	10, 200. 36
1, 000	9, 784. 49	10, 217. 46	$1s_2-2p_8$	10, 217. 49
1	9, 774. 79	10, 227. 60	$3s_1''''-7U$	10, 227. 86
8	9, 677. 80	10, 330. 10	$3d_1'-6V$	10, 329. 97
6	9, 673. 39	10, 334. 80	$3d_1'-6Y$	10, 334. 79
50	9, 666. 86	10, 341. 79	$3d_1'-6U$	10, 341. 62
1, 500	9, 657. 76	10, 351. 53	$1s_4-2p_{10}$	10, 351. 44
4	9, 595. 09	10, 419. 14	$3d_1'-5W$	10, 419. 01
1	9, 593. 67	10, 420. 68	$3d_1'-5Z$	10, 420. 42
5	9, 561. 60	10, 455. 63	$3d_4'-5p_9$	10, 455. 45
4	9, 555. 2	10, 462. 6	$3d_3-4p_4$	10, 462. 42
2	9, 547. 73	10, 470. 83	$3d_3-4p_2$	10, 470. 61
3	9, 486. 02	10, 538. 94	$2p_{10}-3s_1''''$	10, 538. 96
50	9, 478. 39	10, 547. 42	$3d_3-5X$	10, 547. 33
100	9, 459. 09	10, 568. 94	$3d_3-5Y$	10, 569. 17
2	9, 446. 57	10, 582. 95	$2s_5-6Y$	10, 583. 20
3	9, 408. 66	10, 625. 59	$3d_4''-6Y$	10, 625. 57
20	9, 402. 69	10, 632. 34	$3d_4''-6U$	10, 632. 40
5	9, 377. 63	10, 660. 64	$\{3s_1''''-6Z$ $\{3s_1''''-6W$	10, 661. 18 10, 660. 84
4	9, 362. 50	10, 677. 98	$\{3s_1''-6Z$ $\{3s_1''-6W$	10, 678. 09 10, 677. 75
200	9, 354. 22	10, 687. 43	$1s_2-2p_7$	10, 687. 42
3	9, 340. 59	10, 703. 03	$2p_{10}-3s_1''$	10, 703. 07
8	9, 334. 80	10, 709. 67	$\{3d_2-7X$ $\{3d_4''-5W$	10, 709. 67 10, 709. 79
1	9, 333. 32	10, 711. 36	$3d_4''-5Z$	10, 711. 20
2	9, 328. 08	10, 717. 38	$3d_2-7Y$	10, 717. 69
2	9, 322. 84	10, 723. 40		
100	9, 291. 58	10, 759. 48	$2p_{10}-2s_3$	10, 759. 52
1	9, 242. 17	10, 817. 00	$3d_5-4p_3$	10, 817. 16

TABLE 3.—*Infra-red spectrum of argon—Continued*

Intensity	λ_{air} I. A.	ν_{vac} cm ⁻¹ observed	Term combination	ν_{vac} cm ⁻¹ calculated
B. S.	B. S.			
1,000	9,224.49	10,837.73	$1s_2-2p_6$	10,837.71
5h	9,221.08	10,841.74	$3s_1'''-6W$	10,841.86
50	9,198.61	10,868.23	$3d_5-5X$	10,868.31
150	9,194.68	10,872.87	$2p_{10}-2s_2$	10,873.01
6	9,180.17	10,890.06	$3d_5-5Y$	10,890.15
500	9,122.95	10,958.36	$1s_5-2p_{10}$	10,958.28
1	9,111.3	10,972.4	$3d_5-4p_1$	10,972.54
60	9,075.42	11,015.75	$2p_2-4d_6$	11,015.64
50	9,073.34	11,018.28	$3d_6-5X$	11,018.44
40	9,066.77	11,026.26	$3d_4-6V$	11,026.34
2	9,057.51	11,037.53	$2p_1-3s_4$	11,037.54
4h	9,057.23	11,037.88	$3d_4-6U$	11,037.99
10	8,994.09	11,115.36	$3d_4-5W$	11,115.38
1	8,992.84	11,116.91	$3d_4-5Z$	11,116.79
3	8,988.20	11,122.65	$3d_3-5p_6$	11,122.69
2	8,970.98	11,144.00	$3d_1'-7V$	11,143.96
2	8,967.39	11,148.46	$3d_1'-7Y$	11,148.49
10	8,964.48	11,152.08	$3d_1'-7U$	11,152.04
40	8,962.19	11,154.93	$2p_2-4d_5$	11,154.97
1	8,895.42	11,238.66	$3d_2-8X$	11,238.81
1	8,891.70	11,243.36	$3d_2-8Y$	11,243.94
4	8,874.84	11,264.72	$2p_{10}-3s_1'$	11,264.82
150	8,849.97	11,296.37	$3d_4'-6V$	11,296.43
1	8,846.17	11,301.23	$3d_4'-6Y$	11,301.25
20	8,840.82	11,308.07	$3d_6-6U$	11,308.08
3	8,840.39	11,308.61		
1	8,819.37	11,335.57	$3d_2-6Z$	11,335.58
3	8,805.16	11,353.86	$3d_5-5p_{10}?$	11,354.45
100	8,799.13	11,361.64	$2p_3-4d_5$	11,361.69
30	8,784.59	11,380.44	$2p_4-4d_6$	11,380.35
200	8,761.72	11,410.12	$2p_2-4d_3$	11,410.19
1	8,741.26	11,436.86	$3d_5-5p_7$	11,436.97
3	8,739.51	11,439.15	$3d_1''-7Y$	11,439.27
20	8,736.63	11,442.92	$3d_1''-7U$	11,442.82
2	8,736.19	11,443.50	$3d_5-5p_6$	11,443.67
5	8,713.79	11,472.91	$3s_1'''-7Z$	11,472.92
3	8,700.95	11,489.84	$3s_1''-7Z$	11,489.83
2	8,690.12	11,504.16	$3d_6-5p_{10}$	11,504.55
60	8,678.43	11,519.66	$2p_4-4d_5$	11,519.68
400	8,667.94	11,533.60	$1s_3-2p_7$	11,533.58
1	8,642.89	11,567.03	$3d_5-5p_5$	11,567.10
100	8,620.47	11,597.11	$2p_5-4d_5$	11,597.10
150	8,605.78	11,616.91	$2p_3-4d_3$	11,616.91
4	8,579.49	11,652.51	$3s_1'''-7W$	11,652.5
5	8,578.06	11,654.45	$1s_2-2p_5$	11,654.45

TABLE 3.—*Infra-red spectrum of argon*—Continued

Intensity	$\lambda_{\text{air I. A.}}$	$\nu_{\text{vac cm}^{-1}}$ observed	Term combi- nation	$\nu_{\text{vac cm}^{-1}}$ calculated
B. S.	B. S.			
1	8, 565. 13	11, 672. 04	$3d_1'-8V$	11, 672. 00
1	8, 563. 38	11, 674. 43	$3d_1'-8Y$	11, 674. 74
3	8, 561. 38	11, 677. 16	$3d_1'-8U$	11, 677. 09
2, 000	8, 521. 442	11, 731. 884	$1s_2-2p_4$	11, 731. 87
2	8, 496. 64	11, 766. 13	$\begin{cases} 3d_1'-6Z \\ 3d_1'-6W \end{cases}$	$\begin{cases} 11, 766. 38 \\ 11, 766. 04 \end{cases}$
40	8, 490. 30	11, 774. 92	$2p_4-4d_3$	11, 744. 90
20	8, 443. 44	11, 840. 27	$3d_4-7V$	11, 840. 33
1	8, 440. 26	11, 844. 73	$3d_4-7Y$	11, 844. 86
6	8, 437. 71	11, 848. 30	$3d_4-7U$	11, 848. 41
2, 500	8, 424. 648	11, 866. 675	$1s_4-2p_8$	11, 866. 73
3, 000	8, 408. 213	11, 889. 870	$1s_2-2p_3$	11, 889. 86
20	8, 399. 35	11, 902. 42	$3d_3-6X$	11, 902. 11
80	8, 392. 28	11, 912. 44	$3d_3-6Y$	11, 912. 57
60	8, 384. 73	11, 923. 17	$2p_3-4d_4$	11, 923. 17
3	8, 367. 03	11, 948. 39	$2p_2-4d_1''$	11, 948. 49
1	8, 355. 30	22, 965. 17	$3d_1''-8Y$	11, 965. 52
4	8, 353. 50	11, 967. 75	$3d_1''-8U$	11, 967. 87
20	8, 332. 21	11, 998. 32	$3d_3-5Z$	11, 998. 20
1	8, 305. 02	12, 037. 60	$3d_1'-9Y$	12, 037. 6
1	8, 303. 79	12, 039. 39	$3d_1'-9U$	12, 039. 39
8	8, 291. 88	12, 056. 68	$3d_4''-6W$	12, 056. 82
1, 500	8, 264. 524	12, 096. 589	$1s_2-2p_2$	12, 096. 58
50	8, 255. 07	12, 110. 44	$3d_4'-7V$	12, 110. 42
4	8, 249. 58	12, 118. 50	$3d_4'-7U$	12, 118. 50
6	8, 224. 72	12, 155. 13	$2p_3-4d_1''$	12, 155. 21
20	8, 203. 42	12, 186. 69	$2p_2-3s_5$	12, 186. 74
20	8, 178. 96	12, 223. 14	$3d_5-6X$	12, 223. 09
40	8, 178. 84	12, 223. 32		
10	8, 171. 95	12, 233. 62	$3d_5-6Y$	12, 233. 55
2	8, 166. 21	12, 242. 22		
3	8, 151. 86	12, 263. 77	$2p_2-3s_4$	12, 263. 75
10	8, 143. 50	12, 276. 36	$2p_3-4d_1'$	12, 276. 36
2	8, 127. 30	12, 300. 83		
50	8, 119. 18	12, 313. 13	$2p_4-4d_1''$	12, 313. 20
4, 000	8, 115. 309	12, 319. 006	$1s_5-2p_9$	12, 319. 00
2, 000	8, 103. 692	12, 336. 665	$1s_4-2p_7$	12, 336. 66
20	8, 094. 06	12, 351. 35	$2p_2-4d_2$	12, 351. 34
5	8, 082. 93	12, 368. 35	$3d_4-8V$	12, 368. 36
20	8, 079. 68	12, 373. 32	$\begin{cases} 3d_6-6X \\ 3d_4-8U \end{cases}$	$\begin{cases} 12, 373. 19 \\ 12, 373. 46 \end{cases}$
20	8, 066. 60	12, 393. 39	$2p_3-3s_5$	12, 393. 46
1	8, 058. 53	12, 405. 80		
100	8, 053. 32	12, 413. 83	$2p_6-4d_5$	12, 413. 84
50	8, 046. 13	12, 424. 92	$2p_7-4d_6$	12, 424. 80
20	8, 037. 23	12, 438. 68	$2p_1-3s_2$	12, 438. 70
2	8, 021. 9	12, 462. 4	$3d_4-6W$	12, 462. 41

TABLE 3.—*Infra-red spectrum of argon—Continued*

Intensity	$\lambda_{\text{air I. \AA.}}$	$\nu_{\text{vac cm}^{-1}}$ observed	Term combination	$\nu_{\text{vac cm}^{-1}}$ calculated
B. S.	B. S.			
800	8,014.785	12,473.515	$1s_5-2p_3$	12,473.57
600	8,006.157	12,486.957	$1s_4-2p_6$	12,486.95
3	7,965.08	12,551.35	$2p_4-3s_5$	12,551.45
2	7,960.84	12,558.04	$2p_3-4d_2$	12,558.06
10	7,956.99	12,564.12	$2p_7-4d_5$	12,564.13
400	7,948.176	12,578.048	$1s_3-2p_4$	12,578.03
20	7,916.45	12,628.45	$2p_4-3s_4$	12,628.46
4	7,910.23	12,638.40	$3d_4'-8V$	12,638.35
1	7,906.91	12,643.69	$3d_4'-8U$	12,643.55
100	7,891.10	12,669.02	$2p_6-4d_3$	12,669.06
40	7,868.20	12,705.90	$2p_5-3s_1$	12,705.88
15	7,861.91	12,716.06	$2p_4-4d_2$	12,716.05
2	7,860.44	12,718.44	$3d_3-7X$	12,718.26
8	7,855.73	12,726.06	$3d_3-7Y$	12,726.27
1	7,853.29	12,730.02	$3d_4-9V$	12,730.04
10	7,814.33	12,793.49	$2p_5-4d_2$	12,793.47
30	7,798.55	12,819.37	$2p_7-4d_3$	12,819.35
200	7,724.210	12,942.749	$1s_3-2p_2$	12,942.74
200	7,723.759	12,943.507	$1s_5-2p_7$	12,943.50
20	7,704.81	12,975.34	$2p_6-4d_4$	12,975.32
2	7,690.10	13,000.16	$3d_4'-9V$	13,000.13
50	7,670.04	13,034.16	$2p_8-4d_5$	13,034.06
4	7,667.03	13,039.28	$3d_5-7X$	13,039.24
2	7,662.3	13,047.3	$3d_5-7Y$	13,047.25
500	7,635.107	13,093.795	$1s_5-2p_6$	13,093.79
50	7,628.86	13,104.52	$2p_2-4s_1''''$	13,104.44
30	7,618.33	13,122.63	$2p_2-4s_1''$	13,122.58

Our results for the infra-red lines in the first spectrum of argon are displayed in Table 3, which is constructed exactly like Table 1. Analysis of these new data has yielded improved values for the four $2s$ terms, has identified all 12 of the $3d$ terms, and extended the f -type sequences, so that the recognition of energy states for neutral argon may now be regarded as complete. The $2s$ terms were evaluated from combinations with Meissner's $2p$ terms, the d terms from Meissner's f and p terms, and the new f terms were based upon combinations with the derived d terms. All of the known spectral terms of the Λ I spectrum are collected in Table 4, which is similar to Table 2.

Radiometric investigation of this spectrum should reveal many intense lines which may be expected from combinations of known terms, but which lie beyond the present limit of photographic detection. Three such lines were observed by Paschen¹⁷ many years ago, their wave lengths (corrected to the I. A. scale) and probable classifications appear at the head of Table 3.

¹⁷ F. Paschen, Ann. d. Phys. (4), vol. 27, p. 537, 1908.

TABLE 4.—Terms in the *A* I spectrum

Electron	<i>f</i>	Term, Paschen notation	<i>m</i> =												
			1	2	3	4	5	6	7	8	9	10	11	12	13
<i>s</i>	{	<i>s</i> ₃	33, 967.70	13, 043.05	7, 428.30	4, 671.41	3, 208.24	2, 339.84	1, 781.51	1, 402.07	1, 132.11	933.22	782.70		
		<i>s</i> ₄	33, 360.86	13, 468.31	7, 351.29	4, 632.09	3, 229.21	2, 328.75	1, 779.56	1, 396.01	1, 127.17				
		<i>s</i> ₃	32, 557.78	12, 249.90	6, 014.82	3, 238.44	1, 776.73	899.88							
		<i>s</i> ₂	31, 711.62	12, 136.41	5, 950.13	3, 229.21	1, 758.19								
<i>p</i>	{	<i>p</i> ₁₀		23, 009.42	10, 451.43	6, 042.50	3, 938.95	2, 799.70	2, 071.83	1, 605.92	1, 267.17	1, 038.82			
		<i>p</i> ₉		21, 648.70	10, 168.70	5, 944.94	3, 903.65	2, 762.38	2, 037.31	1, 591.58					
		<i>p</i> ₈		21, 494.13	10, 112.12	5, 919.48	3, 890.65	2, 754.70	2, 031.60	1, 586.42					
		<i>p</i> ₇		21, 024.20	9, 960.10	5, 840.46	3, 856.43	2, 735.10	2, 038.79	1, 579.91	1, 258.13				
		<i>p</i> ₆		20, 873.91	9, 927.84	5, 840.46	3, 849.73	2, 730.41	2, 036.53	1, 577.61	1, 257.65				
		<i>p</i> ₅		20, 057.17	9, 548.47	5, 641.13	3, 726.30	2, 672.00	1, 988.81	1, 549.49		1, 009.72	841.44		
		<i>p</i> ₄		19, 979.75	8, 703.94	4, 510.00	2, 467.81	1, 327.71							
		<i>p</i> ₃		19, 821.76	8, 642.38	4, 476.24	2, 452.93	1, 319.48							
		<i>p</i> ₂		19, 615.04	8, 651.83	4, 501.81	2, 460.37	1, 334.11							
		<i>p</i> ₁		18, 388.83	8, 240.51	4, 320.86	2, 361.52	1, 279.98	587.23						
		<i>d</i>	{	<i>d</i> ₁ '											
<i>d</i> ₂					13, 394.64	7, 545.4	4, 781.81	3, 279.03	2, 396.35	1, 817.83	1, 430.78	1, 154.08	948.33		
<i>d</i> ₃					13, 636.42	7, 666.55	4, 829.28	3, 284.65	2, 419.50	1, 820.18	1, 440.06	1, 165.78	949.02	798.56	
<i>d</i> ₄					12, 963.84	7, 263.70	4, 597.22	3, 176.53	2, 323.11	1, 779.56					
<i>d</i> ₅					14, 972.42	8, 204.85	5, 024.56		2, 507.57		1, 473.54	1, 178.80	951.68	808.88	690.69
<i>d</i> ₆					14, 361.10	8, 087.81	5, 075.38	3, 458.28	2, 501.59	1, 891.62					
<i>d</i> ₇					14, 091.01	7, 898.59	4, 951.29	3, 339.54	2, 461.97	1, 842.03	1, 479.81	1, 178.94	956.92	806.22	684.43
<i>d</i> ₈					15, 293.40	8, 490.07	5, 178.63	3, 643.51	2, 556.59	1, 975.62	1, 498.39	1, 212.87	1, 011.98	818.80	698.52
<i>s</i> ₁ '					15, 443.50	8, 599.40	5, 317.39	3, 602.55	2, 534.77	1, 948.52	1, 516.41	1, 215.82			
<i>s</i> ₁ ''					11, 744.60	6, 099.53	3, 302.90	1, 828.46	1, 205.00	522.72					
<i>s</i> ₁ '''					12, 306.35	6, 492.46	3, 738.54	2, 045.03	1, 021.95						
<i>s</i> ₁ ''''					12, 289.44	6, 357.99	3, 554.04	1, 961.50	1, 038.32						
<i>f</i>	{	<i>s</i> ₁													
		<i>X</i>													
		<i>Y</i>			6, 922.91		4, 425.09	3, 070.31	2, 254.16	1, 725.03					
		<i>Z</i>			6, 881.55		4, 403.25	3, 059.85	2, 246.15	1, 719.90					
		<i>U</i>			5, 456.96		2, 974.22	1, 628.26	816.52						
		<i>V</i>					4, 393.45	3, 053.02	2, 242.60	1, 717.55	1, 355.25				
<i>W</i>					4, 415.67	3, 064.67	2, 250.68	1, 722.65	1, 360.97						

3. KRYPTON

The first spectrum of krypton was analyzed simultaneously by Gremmer¹⁸ and by Meggers, de Bruin, and Humphreys.¹⁹ Our preliminary description and analysis was extended²⁰ two years later, when the number of observed and classified lines was doubled. Gremmer²¹ then reported his own analysis to be in perfect agreement with ours if a revised interpretation be given to six of our levels. Up to this time eight of the $3d$ terms were still lacking. With long exposures Rasmussen²² recorded additional lines mainly in the red and infra-red which led to the identification of five of the missing $3d$ terms, an extension of the terms and a few minor changes among the higher terms.

TABLE 5.—Infra-red spectrum of krypton

Intensity	$\lambda_{\text{air I. A.}}$	$\nu_{\text{vac cm}^{-1}}$ observed	Term combination	$\nu_{\text{vac cm}^{-1}}$ calculated
1	12, 124	8, 245. 9	$1s_2-2p_5$	8, 246. 153
1?	11, 996. 8	8, 333. 28	$3d_3-4Y?$	8, 333. 64
5	11, 819. 3	8, 458. 43	$2p_{10}-2s_5?$	8, 458. 43
1	11, 611. 7	8, 609. 65	$2s_4-5Y$	8, 609. 56
5	11, 457. 4	8, 725. 60	$2p_{10}-2s_4$	8, 725. 60
3	11, 259. 0	8, 879. 35	$3d_5-4X$	8, 879. 48
6	11, 257. 7	8, 880. 38	$3d_5-4Z$	8, 880. 28
3	11, 187. 0	8, 936. 50	$3d_5-4Y$	8, 936. 30
20	10, 874. 84	9, 193. 02	$3d_6-4X$	9, 193. 02
5	10, 699. 2	9, 343. 93	$3d_4'-4p_9$	9, 343. 62
3	10, 626. 5	9, 407. 86	$3d_1'-5U$	9, 407. 80
5	10, 608. 37	9, 423. 94	$3d_1'-5Y$	9, 424. 32
30	10, 592. 97	9, 437. 64	$3d_1'-5W$	9, 437. 71
1	10, 575. 48	9, 453. 25	$3d_3-4p_8$	9, 453. 07
1	10, 486. 28	9, 533. 66	$3d_3-4p_7$	9, 533. 60
5	10, 458. 56	9, 558. 93	$3d_3-4p_6$	9, 558. 97
10	10, 374. 44	9, 636. 44	$3d_1''-5Y$	9, 636. 15
100	10, 360. 37	9, 649. 52	$3d_1''-5W$	9, 649. 54
2	10, 322. 88	9, 684. 56	$2p_3-5d_6$	9, 684. 47
80	10, 296. 93	9, 708. 97	$2p_5-4d_5$	9, 708. 904
2	10, 273. 6	9, 831. 02	$2p_2-5d_5$	9, 831. 00
10	10, 147. 68	9, 851. 77	$2p_2-5d_3$	9, 851. 75
30	10, 120. 96	9, 877. 78	$2p_3-5d_3$	9, 877. 77
10	10, 077. 66	9, 920. 22	$3d_5-4p_{10}$	9, 920. 29
10	10, 065. 96	9, 931. 75	$2p_2-5d_4$	9, 931. 739
2	10, 054. 86	9, 942. 72	$2s_4-6Z$	9, 942. 53
3	10, 038. 65	9, 958. 77	$2s_4-6Y?$	9, 958. 18
1	9, 989. 3	10, 008. 0	$2p_4-5d_6$	10, 007. 70
3	9, 917. 60	10, 080. 32	$2p_4-5d_5$	10, 080. 25
4	9, 916. 37	10, 081. 57	$3d_1'-5p_6$	10, 081. 47

¹⁸ W. Gremmer, *Zeitschr. f. Phys.*, vol. 54, p. 199, 1929.¹⁹ W. F. Meggers, T. L. de Bruin, and C. J. Humphreys, *B. S. Jour. of Research*, vol. 3 (RP89), p. 129, 1929.²⁰ W. F. Meggers, T. L. de Bruin, and C. J. Humphreys, *B. S. Jour. of Research*, vol. 7 (RP364), p. 643, 1931.²¹ W. Gremmer, *Zeitschr. f. Phys.*, vol. 73, p. 620, 1932.²² E. Rasmussen, *Zeitschr. f. Phys.*, vol. 73, p. 779, 1932.

TABLE 5.—*Infra-red spectrum of krypton*—Continued

Intensity	λ_{air} I. A.	ν_{vac} cm ⁻¹ observed	Term combination	ν_{vac} cm ⁻¹ calculated
2	9, 897. 08	10, 101. 22	$2p_2-5d_1'$	10, 101. 18
4	9, 862. 95	10, 136. 18	$3d_5-4p_7$	10, 136. 26
500	9, 856. 24	10, 143. 08	$2p_6-3s_1''''$	10, 143. 06
5	9, 838. 33	10, 161. 54	$3d_5-4p_6$	10, 161. 63
2h	9, 810. 27	10, 190. 61	$3d_2-6X$	10, 190. 60
3	9, 794. 89	10, 206. 60	$3d_2-6Y$	10, 206. 61
2	9, 768. 69	10, 233. 98	$3d_6-4p_{10}$	10, 233. 83
2, 000	9, 751. 74	10, 251. 77	$1s_4-2p_{10}$	10, 251. 750
50	9, 743. 11	10, 260. 85	$3d_4-5U$	10, 260. 80
2h	9, 727. 51	10, 277. 31	$3d_4-5Y$	10, 277. 32
1	9, 722. 78	10, 282. 30	$3d_1''-5p_7$	10, 281. 85
15	9, 714. 85	10, 290. 70	$3d_4-5W$	10, 290. 71
50	9, 704. 22	10, 301. 97	$2p_7-3s_1''''$	10, 302. 01
10	9, 687. 83	10, 319. 40	$2p_6-3s_1''''$	10, 319. 35
2	9, 682. 26	10, 325. 34	$3d_5-4p_5$	10, 325. 32
1	9, 669. 03	10, 339. 47	$2p_3-5d_2$	10, 339. 64
3	9, 615. 63	10, 396. 88	$2p_4-5d_1''$	10, 396. 89
1	9, 607. 2	10, 406. 0		
30	9, 540. 89	10, 478. 33	$2p_7-3s_1''$	10, 478. 30
1	9, 532. 3	10, 487. 8	$2p_1-6d_5$	10, 487. 87
20	9, 450. 88	10, 578. 13	$2p_6-3s_1''''$	1p, 578. 09
100	9, 362. 03	10, 678. 52	$2p_6-4d_5$	10, 678. 428
100	9, 352. 23	10, 689. 61	$3d_4'-5U$	10, 689. 72
1	9, 337. 9	10, 706. 1	$3d_4'-5Y$	10, 706. 24
10	9, 326. 03	10, 719. 74	$3d_4'-5W$	10, 719. 63
1	9, 299. 40	10, 750. 43	$3d_3-3p_4$	10, 750. 58
1	9, 287. 87	10, 763. 78	$3d_1'-6U$	10, 763. 85
2	9, 279. 9	10, 773. 0	$3d_1'-6Y$	10, 772. 94
8	9, 273. 02	10, 781. 02	$3d_1'-6W$	10, 781. 04
10	9, 270. 96	10, 783. 41	$3d_3-5Z$	10, 783. 41
1	9, 262. 69	10, 793. 04	$3d_3-5X$	10, 793. 04
30	9, 243. 54	10, 815. 40		
1	9, 243. 00	10, 816. 03	$3d_3-5Y$	10, 815. 97
1	9, 234. 16	10, 826. 39	$3d_3-3p_3$	10, 826. 50
1	9, 224. 83	10, 837. 34	$2p_7-4d_5$	10, 837. 372
2	9, 188. 69	10, 879. 96	$3d_3-3p_2$	10, 880. 09
20	9, 122. 49	10, 958. 91	$2p_8-3s_1''''$	10, 959. 02
20	9, 111. 69	10, 971. 90	$2p_6-3s_1''''$	10, 972. 00
1	9, 100. 58	10, 985. 30	$3d_1''-6Y$	10, 984. 77
4h	9, 094. 33	10, 992. 85	$3d_1''-6W$	10, 992. 87
3	9, 044. 47	11, 053. 45	$2p_5-3s_1'$	11, 053. 49
30	8, 999. 19	11, 109. 06	$2p_7-4d_6$	11, 109. 076
1?	8, 978. 5	11, 134. 6	$3d_3-3p_1?$	11, 133. 89
50	8, 977. 99	11, 135. 20	$2p_8-3s_1''$	11, 135. 31
10	8, 967. 53	11, 148. 29	$2p_6-3s_1''$	11, 148. 29
2, 000	8, 928. 6934	11, 196. 7764	$1s_5-2p_{10}$	11, 196. 776
2	8, 925. 3	11, 201. 0		
4	8, 870. 32	11, 270. 46		
3	8, 842. 46	11, 305. 97	$3d_4'-5p_9$	11, 305. 63
20	8, 805. 78	11, 353. 06	$3d_5-3p_4$	11, 353. 24

TABLE 5.—*Infra-red spectrum of krypton—Continued*

Intensity	λ_{air} I. A.	ν_{vac} cm ⁻¹ observed	Term combination	ν_{vac} cm ⁻¹ calculated
30	8, 780. 25	11, 386. 07	3d ₅ -5Z	11, 386. 07
6, 000	8, 776. 7498	11, 390. 6150	1s ₄ -2p ₈	11, 390. 615
50	8, 774. 05	11, 394. 12	2p ₈ -3s ₁ '	11, 394. 05
4	8, 773. 00	11, 395. 48	3d ₅ -5X	11, 395. 70
150	8, 764. 09	11, 407. 08	2p ₉ -3s ₁ '	11, 407. 03
30	8, 755. 20	11, 418. 65	3d ₅ -5Y	11, 418. 63
2	8, 747. 29	11, 428. 97	3d ₅ -3p ₃	11, 429. 16
3	8, 746. 43	11, 430. 10	2p ₂ -6d ₃	11, 430. 17
1	8, 742. 49	11, 435. 25	2p ₁ -7d ₅	11, 435. 27
8	8, 726. 54	11, 456. 15	2p ₃ -6d ₃	11, 456. 19
1	8, 722. 17	11, 461. 76	3d ₃ -5p ₇	11, 461. 85
2	8, 713. 62	11, 473. 14	3d ₃ -5p ₈	11, 473. 16
40	8, 697. 50	11, 494. 40	2p ₈ -4d ₅	11, 494. 389
2	8, 673. 48	11, 526. 23	2p ₂ -6d ₄	11, 526. 30
8	8, 651. 49	11, 555. 66	2p ₅ -4d ₂	11, 555. 57
1	8, 632. 81	11, 580. 54	3d ₁ '-7U	11, 580. 58
1	8, 631. 5	11, 582. 3	2p ₂ -6d ₁ '	11, 582. 39
1h	8, 628. 70	11, 586. 05	3d ₁ '-7Y	11, 586. 06
4h	8, 624. 82	11, 591. 26	3d ₁ '-7W	11, 591. 35
40	8, 605. 85	11, 616. 81	3d ₄ -6U	11, 616. 85
1	8, 599. 4	11, 625. 5	3d ₄ -6Y	11, 625. 94
10	8, 593. 1	11, 634. 05	3d ₄ -6W	11, 634. 04
20	8, 569. 02	11, 666. 74	3d ₆ -3p ₄	11, 666. 78
50	8, 560. 89	11, 677. 82	2p ₅ -3s ₄	11, 677. 83
40	8, 537. 93	11, 709. 23	3d ₆ -5X	11, 709. 24
3, 000	8, 508. 8736	11, 749. 2128	1s ₂ -2p ₄	11, 749. 213
30	8, 498. 21	11, 763. 96	2p ₆ -2s ₂	11, 763. 975
2	8, 477. 20	11, 793. 11	2p ₆ -4d ₄	11, 793. 139
2h	8, 469. 96	11, 803. 19	3d ₁ '-7W	11, 803. 18
100	8, 412. 45	11, 883. 89	2p ₆ -4d ₃	11, 883. 903
15	8, 384. 90	11, 922. 93	2p ₇ -2s ₂	11, 922. 919
5	8, 375. 93	11, 935. 70		
1	8, 332. 73	11, 997. 58	3d ₅ -5p ₁₀	11, 997. 67
2	8, 321. 09	12, 014. 36		
10	8, 303. 20	12, 040. 24	2p ₆ -4d ₁ '	12, 040. 15
20	8, 301. 39	12, 042. 87	2p ₇ -4d ₃	12, 042. 847
5, 000	8, 298. 1091	12, 047. 6312	1s ₄ -2p ₇	12, 047. 632
4h	8, 287. 56	12, 062. 96	3d ₄ '-6W	12, 062. 96
1, 500	8, 281. 05	12, 072. 45	1s ₂ -2p ₃	12, 072. 446
100	8, 272. 36	12, 085. 13	2p ₆ -4d ₁ '	12, 085. 16
3, 000	8, 263. 2412	12, 098. 4676	1s ₂ -2p ₂	12, 098. 465
10h	8, 228. 89	12, 148. 97	3d ₃ -6X	12, 148. 58
6	8, 222. 69	12, 158. 13	2p ₂ -4s ₁ '	12, 158. 08
80	8, 218. 40	12, 164. 48	3d ₃ -6Y	12, 164. 59
1	8, 210. 1	12, 176. 8	2p ₂ -4s ₁ '	12, 176. 91
40	8, 206. 62	12, 181. 94	2p ₇ -3s ₁ '	12, 181. 96
20	8, 205. 22	12, 184. 02	2p ₃ -4s ₁ '	12, 184. 10
50	8, 195. 07	12, 199. 11	2p ₇ -4d ₁ '	12, 199. 10
2	8, 192. 4	12, 203. 1	2p ₃ -4s ₁ '	12, 202. 93
3, 000	8, 190. 0570	12, 206. 5759	1s ₄ -2p ₆	12, 206. 576

TABLE 5.—*Infra-red spectrum of krypton*—Continued

Intensity	λ_{air} I. A.	ν_{vac} cm ⁻¹ observed	Term combination	ν_{vac} cm ⁻¹ calculated
15	8, 144. 96	12, 274. 16	$2p_{10}-3s_1''$	12, 274. 18
60	8, 132. 98	12, 292. 24	$2p_2-4s_1'''$	12, 292. 40
6, 000	8, 112. 9023	12, 322. 6615	$1s_5-2p_9$	12, 322. 662
4, 000	8, 104. 3660	12, 335. 6408	$1s_5-2p_8$	12, 335. 641
500	8, 104. 02	12, 336. 17	$2p_9-4d_4'$	12, 336. 17
1, 500	8, 059. 5053	12, 404. 3030	$1s_3-2p_4$	12, 404. 302
8h	8, 040. 50	12, 433. 62	$3d_4-7U$	12, 433. 58
1	8, 039. 8	12, 434. 7		
2h	8, 033. 52	12, 444. 43	$3d_4-7W$	12, 444. 35
5	7, 993. 12	12, 507. 32	$2p_4-4s_1'$	12, 507. 33
2	7, 990. 78	12, 510. 99		
100	7, 982. 42	12, 524. 08	$2p_8-3s_5$	12, 524. 142
30	7, 981. 82	12, 525. 05	$2p_8-4d_2$	12, 525. 09
20	7, 981. 19	15, 526. 02	$2p_4-4s_1''$	12, 526. 16
1	7, 962. 62	12, 555. 23	$3d_5-6p_8$	12, 555. 12
2	7, 957. 67	12, 563. 04	$2p_2-7d_1'$	12, 562. 92
20	7, 946. 99	12, 579. 92	$2p_8-2s_2$	12, 579. 936
2	7, 938. 34	12, 593. 63	$2p_8-7d_3$	12, 593. 62
180	7, 928. 602	12, 609. 100	$2p_8-4d_4$	12, 609. 100
40	7, 920. 47	12, 622. 05	$2p_8-4d_4$	12, 622. 079
200	7, 913. 443	12, 633. 254	$2p_{10}-4d_5$	12, 633. 254
30	7, 904. 62	12, 647. 35	$2p_8-3s_4$	12, 647. 35
10	7, 882. 36	12, 683. 07	$2p_7-3s_5$	12, 683. 086
30	7, 881. 76	12, 684. 03	$2p_7-4d_2$	12, 684. 04
2	7, 871. 93	12, 699. 88	$2p_8-4d_3$	12, 699. 864
20	7, 863. 91	12, 712. 81	$2p_9-4d_3$	12, 712. 843
800	7, 854. 823	12, 727. 535	$1s_3-2p_3$	12, 727. 535
4	7, 840. 40	12, 750. 96	$3d_5-6X$	12, 751. 24
8h	7, 840. 01	12, 751. 58	$3d_5-6Z$	12, 751. 60
2h	7, 830. 21	12, 767. 54	$3d_5-6Y$	12, 767. 25
50	7, 806. 52	12, 806. 29	$2p_7-3s_4$	12, 806. 30
2	7, 786. 66	12, 838. 95	$2p_8-3s_1'$	12, 838. 97
40	7, 776. 28	12, 856. 09	$2p_8-4d_1''$	12, 856. 11
5h	7, 772. 40	12, 862. 50	$3d_4'-7U$	12, 862. 50
5	7, 768. 43	12, 869. 08	$2p_9-4d_1''$	12, 869. 09
1	7, 765. 89	12, 873. 29	$3d_4'-7W$	12, 873. 27
3	7, 749. 16	12, 901. 08	$2p_8-4d_1'$	12, 901. 12
150	7, 746. 831	12, 904. 958	$2p_{10}-4d_6$	12, 904. 958
40	7, 741. 39	12, 914. 03	$2p_9-4d_1'$	12, 914. 10
1h	7, 712. 0	12, 963. 2	$3d_4-8U$	12, 963. 7
1h	7, 709. 0	12, 968. 3	$3d_3-7Z$	12, 968. 1
2h	7, 703. 41	12, 977. 70	$3d_3-7Y$	12, 977. 71
1, 200	7, 694. 5401	12, 992. 6577	$1s_5-2p_7$	12, 992. 658
1, 000	7, 685. 2472	13, 008. 3682	$1s_2-2p_1$	13, 008. 368
4	7, 652. 16	13, 064. 62	$3d_6-6X$	13, 064. 78
4, 000	7, 601. 5465	13, 151. 6027	$1s_5-2p_6$	13, 151. 602

TABLE 6.—Terms of the Kr I spectrum

Electron	<i>j</i>	Term, Paschen notation	<i>m</i> =										
			1	2	3	4	5	6	7	8	9	10	11
<i>s</i>	2	<i>s</i> ₅	32, 943.165	13, 287.967	7, 267.421	4, 589.89	3, 162.96	2, 306.57	1, 760.51	1, 387.08			
	1	<i>s</i> ₄	31, 998.139	13, 020.79	7, 144.21	4, 541.83	3, 135.59	2, 295.92	1, 744.08	1, 374.03			
	0	<i>s</i> ₃	27, 723.281										
	1	<i>s</i> ₂	27, 068.192	8, 027.588									
<i>p</i>	1	<i>p</i> ₁₀		21, 746.389	10, 027.695	5, 909.57	3, 832.19	2, 734.83	2, 042.48	1, 564.98			
	3	<i>p</i> ₉		20, 020.503	9, 799.251	5, 773.85	3, 811.84	2, 705.35	2, 019.12				
	2	<i>p</i> ₈		20, 607.624	9, 793.745	5, 774.13	3, 809.12	2, 705.06					
	1	<i>p</i> ₇		19, 950.507	9, 601.415	5, 693.60	3, 765.35	2, 680.06					
	2	<i>p</i> ₆		19, 791.563	9, 552.277	5, 668.23	3, 754.04	2, 672.08	1, 998.84	1, 550.40			
	0	<i>p</i> ₅		18, 822.039	9, 153.252	5, 504.54	3, 618.73	2, 606.77	1, 958.67	1, 524.57			
	1	<i>p</i> ₄		15, 318.979	4, 476.620								
	1	<i>p</i> ₃		14, 893.746	4, 400.695								
	2	<i>p</i> ₂		14, 963.727	4, 347.112								
	0	<i>p</i> ₁		14, 059.824	4, 093.310								
	3	<i>d</i> _{1'}		13, 835.55									
<i>d</i>	2	<i>d</i> _{2'}		14, 047.38		7, 706.40	4, 808.55	3, 335.88	2, 406.81	1, 835.85	1, 440.83	1, 160.56	
	1	<i>d</i> ₃		13, 269.22		7, 751.41	4, 922.09	3, 387.34	2, 418.23	1, 843.46	1, 447.56		
	2	<i>d</i> _{4'}		15, 227.20		7, 266.47	4, 656.11	3, 226.14	2, 400.86	1, 810.54			
	4	<i>d</i> _{5'}		15, 117.47		7, 907.660	5, 117.98	3, 539.56	2, 402.13	1, 867.81	1, 469.52	1, 183.77	
	3	<i>d</i> _{6'}		14, 688.55		8, 284.33	5, 138.010	3, 480.96	2, 511.28	1, 896.05	1, 481.82	1, 189.70	976.20
	4	<i>d</i> _{7'}		15, 828.86		7, 998.424	5, 037.988	3, 443.43	2, 444.44	1, 864.48	1, 464.48	1, 178.05	908.00
	1	<i>d</i> _{8'}		16, 143.40		9, 113.135	5, 238.73	3, 571.95	2, 624.55	1, 911.91	1, 486.34	1, 196.75	
	0	<i>d</i> _{9'}		7, 768.55		8, 841.431	5, 311.28	3, 583.95	2, 579.23	1, 981.54	1, 502.47	1, 206.59	
	1	<i>s</i> _{1'}		9, 472.21		2, 811.65							
	2	<i>s</i> _{1''}		9, 213.47		2, 792.82							
	3	<i>s</i> _{1'''}				2, 677.33							
	2	<i>s</i> _{1''''}		9, 048.50									
<i>f</i>	1	<i>X</i>		6, 950.38			4, 334.16	3, 078.62	2, 250.64	1, 727.10	1, 364.65	1, 105.03	
	2	<i>Y</i>		6, 893.56			4, 411.23	3, 062.61	2, 249.49	1, 722.3			
	2	<i>Z</i>		6, 949.58			4, 443.79	3, 078.26	2, 259.1	1, 724.8	1, 362.4	1, 102.82	
		<i>U</i>					4, 427.75	3, 071.70	2, 254.97	1, 715.3			
		<i>W</i>					4, 397.84	3, 054.51	2, 244.20				

The present investigation of the infra-red spectrum of krypton with mesocyanine and xenocyanine plates yields 200 lines, more than half of which have never been observed before. Analysis of these data brings the discovery of spectral terms nearer completion and firmly establishes the nature of some terms previously known but misinterpreted on account of unobserved combinations. The corrections suggested by Gremmer are justified, and most of the extensions and revisions of terms by Rasmussen are confirmed. The results for the observed and classified lines of krypton are presented in Table 5 in the same manner as they were shown for neon and argon in Tables 1 and 3, respectively. Wave lengths given to more than 2 decimal places are quoted from the interferometer measurements by Humphreys.²³ Such values fix the relative values of combining terms very accurately and thus permit the calculation of other wave lengths with somewhat higher precision than can be claimed for ordinary grating measurements. A complete list of the Kr I terms now available is given in Table 6, which is comparable with Tables 2 and 4 for Ne I and A I spectra, respectively. The $2s_4$ term at 13,020.79 is checked by double-electron ($s-f$) transitions, but no such combinations were observed for the $2s_5$ term, which was placed at 13,287.96 on the assumption that the otherwise unclassified line at 8,458.43 Å represented the transition $2p_{10}-2s_5$.

Radiometric investigation of this spectrum is recommended to those equipped to undertake it because many of the expected combinations of known terms still lie beyond the range of present photographic materials.

WASHINGTON, November 26, 1932.

²³ C. J. Humphreys, B. S. Jour. of Research, vol. 5 (R P 245), p. 1041; 1930.



